

SPECTRUM OF DOUBLY-IONISED CADMIUM

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ABSTRACT. An experimental investigation of the spark spectrum of cadmium has been made, the range of spectrum extending from $\lambda 2200$ to 370\AA . The lines corresponding to different stages of ionisation have been sorted out by introducing inductance in the spark circuit. 134 new lines of Cd III have been classified identifying 29 new terms which consist of $4d^9 6s$, $4d^9 5d$ and 7 undesignated terms. The term values have been calculated by means of the $5s-5p$ and $5p-6s$ groups of lines. The value obtained for the deepest term, $4d^{10} 1S_0$, is 308463 cm^{-1} ; the corresponding ionisation potential is about 38 volts.

EXPERIMENTAL

The experimental part of this investigation was carried out at 'Upsala,' Sweden, in 1931-32 when the writer was working under the Late Prof. A. Fowler, F.R.S., in the Imperial College of Science and Technology, London, on the isoelectronic spectra of Cu, Zn, Ag, Cd, etc. Through the kindness of Prof. Siegbahn the spectra of the above elements were taken in the Physical Laboratory at Upsala with two 'grazing incidence' spectrographs. In one, the grating was of radius 1.5 metres and in the other, 1 metre. The source employed was the 'hot spark' excited by means of rectified and condensed current of tension of about 50 to 70 kilo-volts. The range of the spectra photographed was from $\lambda 2200$ to 370\AA , the dispersion varying from 5.71\AA per mm. at 2200\AA to 2.80\AA per mm. at 400\AA . The definition was extremely good and the lines as close as 0.10\AA were clearly separated.

The lines belonging to the different stages of ionisation were distinguished from each other by inserting some suitable inductance in the spark circuit. By adjusting the amount of inductance and the time of exposure the lines of Cd III were obtained with approximately the same intensity with and without inductance. Cd IV lines were prominent without inductance and suppressed with inductance. The reverse was the case with the Cd II lines. The lines of which the intensities are equal with and without inductance or differ by '1' are taken to be the Cd III lines—the most prominent lines having been given the intensity '10.' The faint lines where this criterion cannot sometimes be applied have been treated as Cd III lines whenever they are found to fit into the analytical scheme.

CLASSIFICATION

The doubly-ionised cadmium is isoelectronic with singly ionised silver and neutral palladium and a general similarity of the three spectra, Cd III, Ag II

and Pd I is to be expected. In accordance with Hund's theory the triplet and singlet terms arising from the atoms in the unexcited and various excited states may conveniently be represented as in Table I which indicates the types of terms arising from the more important configuration shown on the left.

TABLE I

4s	4p	4d	4f	5s	5p	5d	5f	6s	6p	Prefix	Terms
2	6	10								$4d^{16}$	1S_0
2	6	9		1						$4d^9 5s$	$^1D, ^3D$
2	6	9			1					$4d^9 5p$	$^1(PDF), ^3(PDF)$
2	6	9						1		$4d^{10} 6s$	$^1D, ^3D$
2	6	9				1				$4d^9 5d$	$^1(SPDFG), ^3(SPDFG)$
2	6	9							1	$4d^9 6p$	$^1(PDF), ^3(PDF)$
2	6	8		2						$4d^8 5s^2$	$^1(SDG), ^3(PF)$
2	6	8		1	1					$4d^8 5s 5p$	$^5(DFG), ^3(DFG), \text{etc.}$

The lines corresponding with the possible combinations of the first three rows have already been measured and identified by Gibbs and White (1928), and independently by McLennan, McLay, and Crawford (1928). In the course of the present investigation all the terms shown in the fourth and the fifth row have been identified. The terms 3F_3 , 3F_3 , 3F_2 and 3P_2 belonging to the configuration $4d^8 5s^2$ and probably the terms 3D_3 , 3F_3 belonging to the configuration $4d^8 5s 5p$ for Pd I have been identified by Shenstone, (1930). But none of the terms belonging to the above two configurations have been identified in the case of Ag II. The terms $3d^8 4s^2$ and $3d^8 4s 4p$ for Ni I (Russel 1929) have been found to give very bright lines in combination with the $3d^9 4p$ and $3d^9 4s$ terms respectively. No traces of these lines have, however, been found in the case of Cu II, though the spectrum was excited by the very powerful method of "hollow cathode" (Kruger, 1929).* But in the case of Zn III the terms $3d^8 4s$ (4F) $4p^5$, $^3(DFG)$ and the terms $3d^8 4s$ (2F) $4p^5$, $^1(DFG)$ have been identified by the present writer (Mazumder, 1936; Mazumder 1934-35). The terms $3d^8 4s^2$ $^1(SGD)$ $^3(PF)$ could not however, be located for Zn III. In the spectrum of Cd III a large number of lines giving the characteristic differences of the $4d^9 5s$ terms appeared just below $\lambda 600\text{\AA}$. These lines do not combine into a Rydberg sequence of $4d^n np$ terms with $4d^9 5p$ terms already known—the expected region for $4d^9(5s-6p)$ lines being in the neighbourhood of $\lambda 700\text{\AA}$. Like Zn III these Cd III lines should then also be due to the combination of $4d^9 5s$ terms with

* Shenstone has, however, later identified the terms $3d^8 4s^2$ and $3d^8 4s 4p$ for Cu II; *Phil. Trans. Roy. Soc.*, 235A, p. 195, March 12, 1936.

$4d^8 5s 5p$ terms. In the absence of the corresponding data for Ag II and Pd I it is difficult to identify the terms $4d^8 5s 5p$ for Cd III. The work is, however, being continued and this part will form the subject matter for a future communication.

A few lines are still available in the region where $4d^8(5p-6s)$ and $4d^8(5p-5d)$ lines appear. Some of these residual lines give characteristic differences of $4d^8 5p$ terms. They probably arise from the combination of $4d^8 5p$ terms with $4d^8 5s^2$ terms. But most of the minor combinations being absent, the lines concerned are here shown as due to the combinations of $4d^8 5p$ terms with a few undesigned terms. It should be remembered that the transition is a double electronic one and all the satellite and intercombination lines may not appear.

There can be no doubt that the strong group of lines $\lambda 2225$ to 1470\AA has been correctly classified by Gibbs and White as arising from the combination of $4d^8 5s$ and $4d^8 5p$ terms. The lines occur in the region which is to be expected from a comparison with corresponding groups in the isoelectronic spectra Pd I and Ag II. By applying the irregular doublet law it is found thus:

		$5s\ ^3D_3$	—	$5p\ ^3D_3$
Pd I	30829	
				16464
Ag II	47293	
				15149
Cd III	62442	

where the $\Delta\nu$'s are in the usual order of agreement in such comparisons. Moreover, the terms of Ag II and Cd III are arranged in the same order of magnitude and the $\Delta\nu$'s in the components of triplets have generally the same sign.

The expected regions for $(5p-6s)$ and $(5p-5d)$ groups of lines are in the neighbourhood of the $(5s-5p)$ group. On examining the lines just below the $(5s-5p)$ group a large number of differences characteristic of the $5p$ terms have been obtained. It has been possible to arrange the lines as due to the possible combinations of $5p$ terms with the $6s$ and $5d$ terms. As mentioned earlier, by means of some of the residual lines a few terms have been obtained which, though left undesigned, are most probably the $4d^8 5s^2$ group of terms.

The $5s$ and $6s$ groups having been established, it has been possible to calculate the absolute term values by means of a simple Rydberg formula. The value for the $5s\ ^3D_3$ term is found to be 228000 cm^{-1} . This places the deepest term $4d^{10}\ ^1S_0$ at 308463 cm^{-1} ; the corresponding ionization potential is about 38 volts.

Comparison of the three Isoelectronic Spectra, Pd I, Ag II and Cd III

It is of interest to compare the term values of isoelectronic spectra Pd I, Ag II and Cd III as in the following table:

The values of the $4d^9 6s$ ($^3, ^1(D)$) Terms

	3D_3	3D_2	3D_1	1D_2
Pd I	18476(216)	18260(3316)	14944(152)	14792
Ag II	56637(377)	56260(4215)	52045(279)	51766
Cd III	104033(488)	103545(5315)	98230(366)	97864

It will be seen that the separations of the terms have systematically increased with the nuclear charge.

Separation of the Triplet D Term

	$4d^9 5s$		$4d^9 6s$	
	(1, 2)	(2, 3)	(1, 2)	(2, 3)
Pd I	2339	1191	3316	216
Ag II	2998	1577	4215	377
Cd III	3866	1900	5315	488

The above figures show that the difference, $^3D_2 - ^3D_1$, has increased with the quantum number, whereas $^3D_3 - ^3D_2$ has decreased. The total separation has, however, remained practically the same. It is evident from this that the separation of the ground terms $4d^9$ $^2D_{3,2}$ of Cd IV will approximately be —

$$(3866 + 1900) + (5315 + 488)/2 \text{ or } 5785 \text{ cm}^{-1}.$$

The actual value found by Green (1941) is 5812; thus the agreement is very close.

Application of the Irregular Doublet Law

	$5s^3D_3$	$5p^3D_3$	$5s^3D_3 - 5p^3D_3$	$(5s^3D_3)^{\frac{1}{2}} - (5p^3D_3)^{\frac{1}{2}} = \Delta(\nu^{\frac{1}{2}})$
PD I	60716	29887	30829	73.5
			16464	
Ag II	138000	90707	47293	70.3
			15147	
Cd III	228000	165560	62440	70.6

According to the irregular doublet law ' $\Delta\nu^{\frac{1}{2}}$ ' is independent of the nuclear charge which is found to be approximately the case from the figures given in the last column. It is interesting to point out that the corresponding figures for Ni I, Cu II, and Zn III given in the author's papers mentioned earlier are 69.1, 71.8 and 72.2 respectively.

In Fig. 1 the Moseley diagrams for terms $4d^{10}$ 1S_0 , $4d^9 5s$ 3D_3 , $5p^3D_3$ and $6s^3D_3$ for the three isoelectronic spectra Pd I, Ag II and Cd III are drawn. The figures for Cd III are based upon $5s^3D_3 = 228000 \text{ cm}^{-1}$ calculated from the data obtained in the present investigation. The curves corresponding to the terms $5s^3D_3$ and $5p^3D_3$ run fairly parallel. All the curves bend slightly downwards with increasing Z .

In Table II the wave numbers of the lines classified as due to the combination of 5p and 6s terms are given. For completeness the (5s-5p) group of lines given by Gibbs and White is also included. The figures just above the wave numbers indicate intensities. The term values written near the respective terms are those obtained by the author.

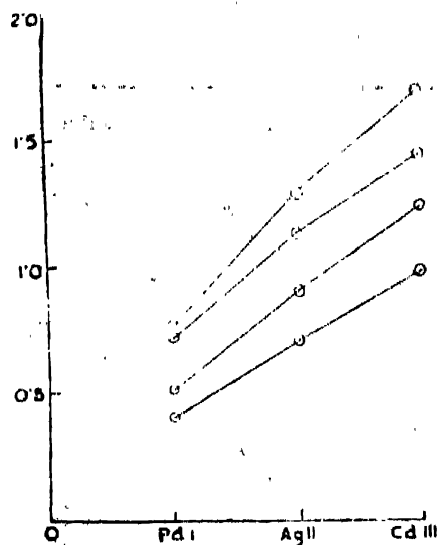


Fig. 1

Moseley diagram for Pd I, Ag II, Cd III

In Table III are given the designation of the terms and the corresponding values; in Table IV, the wave-length, wave numbers, intensities and classification. The lines against which the letters G. and W. have been written are those classified by Gibbs and White; but the wave-length, frequencies and intensities mentioned are those obtained in the present investigation except for

a few lines at the end of the table where the original figures have been retained. Against some of the lines "Gr IV" has been written; these have also been used by Green in his analysis of Cd IV lines. Some of these lines

TABLE II

$4d^95p$	$4d^{10}$ 1S_0 308463	3D_3 228000	1900^3D_2 226100	$4d^95s$ 3866^3D_1 222234	2652^1D_2 219582	3D_3 104033	$4d^96s$ 488^3D_2 103545	531^3D_1 98230	366^1D_2 97864
169422 3F_4	—	15	—	—	—	4	—	—	—
—2818	—	58578	—	—	—	65390	—	—	—
172240 3F_3	—	12	15	—	8	3	5	—	*
6541	—	55760	53859	—	47341	68207	68696	—	—
165699 3F_2	—	1	10	10	9	1	4	4	3
130	—	62300	60399	56535	53883	—	62152	67407	67835
105560 3D_3	—	12	8	—	9	4	4	—	2
—2464	—	62439	60537	—	54022	61527	62015	—	67696
168024 3D_2	—	1	7	12	5	1	3	4	2
7197	—	59971	58075	54211	51557	—	64478	69793	70160
160827 3D_1	8	—	7	10	4	—	1	4	*
—13814	147637	—	65270	61405	58753	—	57282	62594	—
174641 3P_2	—	15	3	1	4	5	5	—	2
4942	—	53359	51459	47592	44941	70609	71096	—	76782
169699 3P_1	8	—	12	5	6	—	3	1	5
3358	138765	—	56400	52535	49882	—	66153	71474	71834
166341 3P_1	—	—	—	8	—	—	—	3	—
3080	—	—	—	55891	—	—	—	68112	—
162361 1F_3	—	5	8	—	12	*	*	—	4
2372	—	65636	63734	—	57219	—	—	—	64497
159989 1D_2	—	4	5	7	12	1	*	4	3
—2389	—	68009	66110	62241	59595	55960	—	51758	62126
162378 1P_1	15	—	3	5	10	—	3	4	3
—	146085	—	63718	59853	57204	—	58834	—	64512

* Missing Inter-combinations.

Missing satellites.

TABLE III

The term values of Cd III

Term	Value	Term	Value	Term	Value
$4d^{10} 1S_0$	308463	$4d^9 5p \ ^3P_4$	169422	$4d^9 6s \ ^3D_3$	104033
$4d^9 5s \ ^3D_3$	228000	" $\ ^3P_3$	172240	" $\ ^3D_2$	103545
" $\ ^3D_2$	226100	" $\ ^3P_2$	165690	" $\ ^3D_1$	98230
" $\ ^3D_1$	222234	" $\ ^3D_3$	165560	" $\ ^1D_2$	97864
" $\ ^1D_2$	219582	" $\ ^3D_2$	168024		
		" $\ ^3D_1$	160827		
		" $\ ^3P_2$	174641		
		" $\ ^3P_1$	169699		
		" $\ ^3P_0$	166341		
		" $\ ^1F_3$	162361		
		" $\ ^1D_2$	159980		
		" $\ ^1P_1$	162378		
$4d^9 5d \ ^3G_5$	103332	$4d^9 5d \ ^3D_2$	101650	$4d^9 5d \ ^1G_4$	104996
" $\ ^3G_4$	103156	" $\ ^3D_1$	98304	" $\ ^1F_3$	88457
" $\ ^3G_3$	108462	" $\ ^3P_2$	100923	" $\ ^1D_2$	98789
" $\ ^3F_4$	98944	" $\ ^3P_1$	103863	" $\ ^1P_1$	95828
" $\ ^3F_3$	103045	" $\ ^3P_0$	101585	" $\ ^1S_0$	100475
" $\ ^3F_2$	97614	" $\ ^3S_1$	105485		
" $\ ^3D_3$	102365				

TABLE IV

The catalogue of the classified lines of doubly-ionized Cadmium

Plate II		Plate III					
Int.	No.	Int.	No.	—	—	—	Classification
—	—	0	1	1256.834	79565		$4d^9 5p \ ^3D_3 - 4d^9 5d \ ^1F_3$
—	—	1	1	61.538	79268		" $\ ^3P_1 - b_0$
—	—	1	1	67.245	78911		" $\ ^3F_4 - d_4$
—	—	0	0 ⁺	68.838	78813		$4d^9 5p \ ^3F_3 - 4d^9 5d \ ^1P_1$
—	—	0 ⁺	0 ⁺	94.750	77235	42	" $\ ^3F_3 - \text{ " } \ ^1F_3$
0	0 ⁺	0	2	1303.395	76782	IV ?	" $\ ^3P_2 - \text{ " } \ 6s \ ^1D_2$
0	1	0	2	13.718	76120	IV ?	" $\ ^3P_2 - b_2$
—	—	0 ⁺	0	26.421	75391		" $\ ^1P_1 - a_0$
—	—	0	1 ⁺	32.335	75053	IV ?	" $\ ^3D_3 - d_4$
0	0 ⁺	0 ⁺	0 ⁺	53.164	73904		" $\ ^1F_3 - 4d^9 5d \ ^3F_3$
1	2	3	3	54.304	73839		" $\ ^3D_1 - a_0$
0 ⁺	0 ⁺	0	0 ⁺	56.389	73725		" $\ ^3P_2 - b_1$
—	—	0	0 ⁺	61.412	73453		" $\ ^3F_3 - 4d^9 5d \ ^3D_3$
3	4	5	5	83.618	72274		" $\ ^3P_2 - \text{ " } \ ^1P_1$
2	3	4	5	85.156	72194		" $\ ^3D_3 - \text{ " } \ ^1P_1$
—	—	1	1	91.807	71850		" $\ ^1F_3 - d_4$
1	3	4	5	92.106	71834	IV ?	" $\ ^3P_1 - 4d^9 6s \ ^1D_2$
4	4	5	5	96.779	71593		" $\ ^3P_2 - \text{ " } \ 5d \ ^3F_3$
1 ⁺	2 ⁺	4	4	97.925	71535		" $\ ^1D_2 - \text{ " } \ ^1F_3$
—	—	1	1	99.101	71474		" $\ ^3P_1 - \text{ " } \ 6s \ ^3D_1$
1 ⁺	2 ⁺	4	5	1400.696	71393	Gr.IV	" $\ ^3P_1 - \text{ " } \ 5d \ ^3D_1$
1	3	3	5	06.564	71096	Gr.IV	" $\ ^3P_2 - \text{ " } \ 6s \ ^3D_2$
3	3	5	5	16.250	70609		" $\ ^3P_2 - \text{ " } \ ^3D_2$
0 ⁺	1	1	1 ⁺	16.627	70590		" $\ ^3F_3 - \text{ " } \ 5d \ ^3D_2$
3	4	6	6 ⁺	18.875	70478		" $\ ^3F_4 - \text{ " } \ ^3F_4$

TABLE IV (contd.)

Plate II		Plate III						Classification
Int.	No.	Int.	No.					
3	3	4	4 ⁻	20.248	70410	Gr. IV		$5d^9 5p^3 \text{ } ^3D_2 - 4d^8 5d^3 \text{ } ^3F_2$
3	3	4	4	20.479	70399			" " $^3D_1 - b_0$
0	0 ⁺	0 ⁺	2	25.311	70160			" " $^3D_2 - 4d^9 6s^1 \text{ } ^1D_2$
3	4	5	5	31.154	69874			$4d^8 5p^3 \text{ } ^3F_3 - \text{ " } 5d^3 \text{ } ^3D_3$
3	4	5	5	1431.154	69874			$4d^8 5p^3 \text{ } ^3F_2 - 4d^9 5d^3 \text{ } ^1P_1$
2	3	3	4	32.815	69793			" " $^3D_2 - \text{ " } 6s^1 \text{ } ^3D_1$
—	—	0	0 ⁺	34.350	69718			" " $^3D_2 - \text{ " } 5d^3 \text{ } ^3D_1$
—	—	0	1	38.861	69500			" " $^3D_2 - b_2$
2	3	4	5	44.580	69224			" " $^3P_1 - 4d^9 5d^3 \text{ } ^1S_0$
1	2	2	3	45.195	69195			" " $^3F_3 - \text{ " } ^3F_3$
4	5	5	5	46.025	69155	G. & W.		" " $^3P_2 - \text{ " } ^3S_1$
5	5	6	5	47.492	69085			" " $^3F_3 - \text{ " } ^3G_4$
4	4	5	5	55.684	68690			" " $^3D_2 - \text{ " } 6s^1 \text{ } ^3D_2$
2	2	3	3	66.132	68207			" " $^3D_2 - \text{ " } ^3D_3$
1	1	2	3	68.175	68112			" " $^3P_0 - \text{ " } ^3D_1$
"	"	"	"	"	"			" " $^3P_1 - \text{ " } 5d^3 \text{ } ^3F_0$
4	4	4	5	68.760	68085			" " $^3F_2 - \text{ " } ^3F_2$
3	3	4	4	1469.495	68051			" " $^3P_1 - \text{ " } ^3D_2$
1	1	2	3	69.760	68038			" " $^3P_0 - \text{ " } ^3D_1$
4	4	4	4	70.400	68009			" " $5s^1 \text{ } ^3D_2 - \text{ " } 5p^1 \text{ } ^1D_2$
4	4	5	5	71.896	67942	Gr. IV ?		" " $5p^1 \text{ } ^3D_3 - \text{ " } 5d^3 \text{ } ^3F_2$
0	1	2	3	74.153	67835			" " $^3F_2 - \text{ " } 6s^1 \text{ } ^1D_2$
0	0 ⁺	1	2	77.225	67696			" " $^3D_3 - \text{ " } ^3D_1$
1	1 ⁺	3	4	82.213	67467			" " $^3F_2 - \text{ " } ^3D_1$
—	—	"	0 ⁺	83.770	67396			" " $^3F_4 - \text{ " } 5d^3 \text{ } ^3D_1$
2	2	3	4	91.262	67058			" " $^3F_4 - \text{ " } ^3D_3$
3	5	4	5	91.785	67034			" " $^3D_3 - b_2$
3	4	4	5	1501.120	66617			" " $^3F_4 - 4d^9$
2	2	3	4	01.600	66594			" " $^3F_4 - C_4$
3	4	4	5	02.680	66548			" " $^1P_1 - 4d^9 5d^3 \text{ } ^1P_1$
3	4	4	5	06.590	66375	IV ?		" " $^3D_2 - \text{ " } ^3D_2$
"	"	"	"	"	"			" " $^3F_4 - \text{ " } ^3F_3$
2	3	3	5	09.090	66265			" " $^3F_4 - \text{ " } ^3G_4$
4	4	5	5	10.980	66182			" " $^3P_2 - \text{ " } ^3G_3$
2	2	3	3	11.640	66153			" " $^3P_1 - \text{ " } 6s^1 \text{ } ^3D_3$
5	5	6	6	12.630	66110			" " $5s^1 \text{ } ^3D_2 - \text{ " } 5p^1 \text{ } ^1F_2$
4	4	double	4	13.100	66090	G. & W.		" " $5p^1 \text{ } ^3F_4 - \text{ " } 5d^3 \text{ } ^3G_5$
—	—	1	1	18.921	65836			" " $^3P_1 - \text{ " } ^3P_1$
—	—	0 ⁺	0 ⁺	22.988	65660			" " $^3D_2 - \text{ " } ^3D_3$
5	5	6	6	23.636	65636			" " $5s^1 \text{ } ^3D_3 - \text{ " } 5p^1 \text{ } ^1F_3$
4	5	5	5	28.380	65429			" " $5p^1 \text{ } ^3P_0 - b_1$
5	5	4	4	29.307	65390			" " $^3F_4 - 4d^9 6s^1 \text{ } ^3D_3$
4	5	5	5	32.090	65270			" " $5s^1 \text{ } ^3D_2 - \text{ " } 5p^1 \text{ } ^3D$
2	3	4	5	38.440	65001			" " $5p^1 \text{ } ^3D_1 - \text{ " } 5d^3 \text{ } ^1P_1$
—	—	1	1	41.427	64791			" " $^3F_2 - b_1$
2	3	4	4	45.170	64718	IV ?		" " $^3P_2 - 4d^9 5d^3 \text{ } ^3P_3$
1	2	2	3	50.090	64512			" " $^1P_1 - \text{ " } 6s^1 \text{ } ^1D_2$
3	3	4	4	50.452	64497			" " $^1F_3 - \text{ " } ^3D_2$
1	3	3	3	50.910	64478			" " $^3D_2 - \text{ " } ^3D_2$
3	4	4	5	52.180	64426			" " $^3F_4 - \text{ " } 5d^3 \text{ } ^1G_4$
3	4	5	6	56.490	64247			" " $^3P_2 - c_3$
1	1 ⁺	2	3	58.537	64163			" " $5p^1 \text{ } ^3D_2 - 4d^9 5d^3 \text{ } ^3P_1$
1	1	2	3	58.655	64158			" " $^1D_2 - \text{ " } ^1P_1$
0 ⁺	1	2	1	60.311	64090			" " $^3F_3 - c_2$
5	5	6	6	60.680	64075			" " $^1P_1 - 4d^9 5d^3 \text{ } ^3D_1$
4	4	4	4	61.355	64047			" " $^3F_2 - \text{ " } ^3D_2$

TABLE IV (contd.)

Plate II		Plate III						Classification	
Int.	No.	Int.	No.						
3	4	4	5	1566.028	63856			4d ⁹ 5p	¹ P ₁ -b ₂
—	—	0	0+	66.508	63836			" "	¹ F ₃ -"
—	—	0+	0	68.180	63768	(78)		" "	³ F ₃ -4d ⁹ 5d ³ G ₃
5	4	6	6	68.988	63734	G. & W.		" 5s	³ D ₂ -", 5p ¹ F ₃
3	2	4	4	69.413	63718	"		" "	" " ¹ P ₁
1	1	2	2	69.691	63707			" 5p	" -d ₂
3	3	4	4	72.615	63588	Gr. IV		" "	¹ P ₁ -4d ⁹ 5d ¹ D ₂
3	1	3	4	73.100	63569			" "	¹ F ₃ -"
—	—	1	1	82.052	63209			" "	³ D ₁ -", " ³ F ₂
4	4	5	6	82.408	63195			" "	³ D ₃ -", " ³ D ₃
—	—	1	1	93.892	62740	(32)		" "	³ D ₃ -C ₄
—	—	0	0+	96.209	62648			" "	³ F ₂ -4d ⁹ 5d ³ F ₃
3	3	4	4	97.598	62594			" "	³ D ₁ -", 6s ³ D ₁
—	—	1	1?	99.092	62536			" "	³ D ₂ -", 5d ³ S ₁
1	1+	2	2	99.444	62521			" "	³ D ₁ -", " ³ D ₁
2	2	3	3	99.668	62513			" "	³ D ₃ -", " ³ F ₃
6	5	6	5	1601.576	62439	G. & W.		" 5s	" " 5p ³ D ₃
1	1	2	2	92.500	62403			" 5p	" " 5d ³ G ₄
0	0+	2	2	93.245	62373			" "	¹ D ₂ -", " ³ F ₂
0+	1	2	3	94.891	62310			" "	³ D ₁ -b ₂
—	—	1	1+	95.142	62300	G. & W.		" 5s	³ D ₃ -4d ⁹ 5p ³ F ₂
5	5	6	6	96.646	62241	"		" "	³ D ₁ -", " ¹ D ₂
1	2	3	4	98.957	62152			" 5p	³ F ₂ -", 6s ³ D ₂
1	2	2	3	99.641	62126			" "	¹ D ₂ -", " ¹ D ₂
—	—	0	0+	11.858	62040			" "	³ D ₁ -", 5d "
1	2	3	4	12.507	62015			" "	³ D ₃ -", 6s ³ D ₂
—	—	0	0+	15.465	61902			" "	¹ P ₁ -", 5d ¹ S ₀
—	—	0+	0+	16.822	61850			" "	³ F ₃ -C ₃
0	1+	2	4	19.223	61758	IV?		" "	¹ D ₂ -4d ⁹ 6s ³ D ₁
0+	1+	2	4?	21.146	61655			" "	" " 5d ³ D ₁
3	3	4	5	25.305	61527			" "	³ D ₃ -", 6s ³ D ₃
—	—	0	0+	26.922	61466			" "	¹ D ₂ -b ₂ ; 4d ⁹ 5p ¹ P ₁ -b ₁
5	5	8	8	28.528	61405	G. & W.		" 5s	³ D ₁ -4d ⁹ 5p ³ D ₁
—	—	1	1	29.128	61383			" 5p	³ F ₂ -d ₂
—	—	1	1	33.990	61200			" "	¹ D ₂ -4d ⁹ 5d ¹ D ₂
—	—	1	1	40.470	60958			" "	³ F ₄ -", " ³ G ₃
—	—	0	1+	42.709	60875	IV?		" "	³ D ₂ -C ₂
—	—	1	1	44.850	60796			" "	¹ P ₁ -4d ⁹ 5d ³ P ₀
0+	2	2	4	46.682	60728	IV?		" "	" " ³ D ₂
—	—	0+	0	51.245	60560			" "	³ D ₃ -", " ¹ G ₄
5	5	6	6	51.872	60537	G. & W.		" 5s	³ D ₂ -", 5p ³ D ₃
5	5	6	6	55.647	60309	"		" "	" " ³ F ₃
1	1	2	0+	56.957	60352			" 5p	³ D ₁ -", 5d ¹ S ₀
—	—	0+	0?	60.666	60217			" "	³ F ₂ -", " ³ S ₁
—	—	2	3	66.795	59995			" "	¹ F ₃ -", " ³ D ₃
—	—	1	1	67.484	59971			" 5s	³ D ₃ -", 5p ³ D ₂
0+	0	2	0	69.200	59909	II?		" 5p	³ D ₁ -b ₁
—	—	1	1	70.206	59873			" "	³ D ₂ -c ₂
4	4	5	5	70.748	59853	G. & W.		" 5s	³ D ₁ -4d ⁹ 5p ¹ P ₁
0	0+	1	1	73.027	59772			" 5p	³ P ₁ -", 5d ³ F ₂
5	5	6	6	78.143	59595	G. & W.		" 5s	¹ D ₃ -", 5p ¹ D ₃
—	—	1	1	78.908	59560			" 5p	³ D ₂ -", 5d ³ G ₃
—	—	2	1	79.878	59528			" "	¹ F ₃ -c ₄
0	0+	1	2	85.846	59317			" "	¹ F ₃ -4d ⁹ 5d ³ F ₂
0	1	2	2+	88.022	59241			" "	³ D ₁ -", " ³ P ₄
1	2	2	3	99.704	58834			" "	¹ P ₁ -", 6s ³ D ₂

TABLE IV (contd.)

Plate II		Plate III						Classification
Int.	No.	Int.	No.					
3	3	4	4	1702.038	58753	G & W.		$4d^9 5s \ ^1D_2 - 4d^9 5p \ ^1D_1$
5	5	10	9	07.156	58578	"		" " $^3D_3 - \text{,,} \text{,,} \ ^3P_4$
—	—	1	0	08.056	58546	"		" $5p \ ^3F_3 - C_2$
—	—	1	1	09.040	58512	"		" " $^1D_1 - 4d^9 5d \ ^3P_1$
—	—	1	1	12.040	58410	"		" " $^3D_3 - C_2$
—	—	1	1	21.273	58007	"		" " $^3D_3 - 4d^9 5d \ ^3P_2$
		double						
5	5	8	8	21.898	58075	"		" $5s \ ^1D_2 - \text{,,} \text{,,} \ 5p \ ^1D_2$
1	2	2	3	22.936	58040	"		" $5p \ ^1F_3 - d_2$
—	—	0	1	43.093	57360	"		" " " $- 4d^9 5d \ ^1G_4$
0	1	2	3	45.743	57282	"		" " $^3F_1 - \text{,,} \text{,,} \ 6s \ ^3D_2$
—	—	1	1	47.071	57230	"		" " $^3D_2 - \text{,,} \text{,,} \ 5d \ ^3G_3$
5	5	8	8	47.657	57210	"		" $5s \ ^1D_2 - \text{,,} \text{,,} \ 5p \ ^1F_3$
5	5	5	5	48.143	57204	"		" " " " " 1P_1
—	—	0	0+	50.069	56945	"		" $5p \ \text{,,} \text{,,} \ 5d \ ^3F_3$
5	5	8	8	68.818	56535	"		" $5s \ ^1D_2 - \text{,,} \text{,,} \ 5p \ ^3P_2$
5	5	8	8	73.013	56400	"		" " $^3D_2 - \text{,,} \text{,,} \ ^3P_1$
—	—	0	0+	86.900	55900	"		" $5p \ ^1D_2 - \text{,,} \text{,,} \ 6s \ ^3D_3$
5	5	6	6	89.208	55801	"		" $5s \ ^3D_1 - \text{,,} \text{,,} \ 5p \ ^3P_0$
—	—	1	0	92.751	55780	"		" $5p \ ^3F_2 - \text{,,} \text{,,} \ 5d \ ^3F_2$
		double						
5	5	8	8	93.402	55760	"		" $5s \ ^3D_3 - \text{,,} \text{,,} \ 5p \ ^3F_3$
—	—	0	1+	97.286	55630	"		" $5p \ \text{,,} \text{,,} \ 5d \ ^3P_2$
—	—	1	1	1808.204	55303	"		" " $^3F_2 - C_3$
—	—	1	1	43.038	54232	S?		" " $^1F_1 - C_2$
6	6	8	8	44.670	54211	G & W.		" $5s \ ^3D_1 - 4d^9 5p \ ^3D_2$
5	5	6	6	51.114	54022	"		" " $^1D_2 - \text{,,} \text{,,} \ ^3D_3$
5	5	5	5	55.858	53883	"		" " " " " 3F_2
6	6	6	6	56.698	53859	"		" " $^3D_2 - \text{,,} \text{,,} \ ^3F_3$
6	6	10	10	74.113	53359	"		" " $^3D_3 - \text{,,} \text{,,} \ ^3F_2$
4	4	5	—	1003.492	52535	"		" " $^3D_1 - \text{,,} \text{,,} \ ^3P_1$
—	5	—	—	39.58	51557	"		" " $^1D_2 - \text{,,} \text{,,} \ ^3D_2$
—	3	—	—	43.31	51459	"		" " $^3D_2 - \text{,,} \text{,,} \ ^3P_2$
—	6	—	—	2004.73	49882	"		" " $^1D_2 - \text{,,} \text{,,} \ ^3P_1$
—	1	—	—	2101.17	47592	"		" " $^3D_1 - \text{,,} \text{,,} \ ^3P_2$
—	8	—	—	2112.31	47341	"		" " $^1D_2 - \text{,,} \text{,,} \ ^3F_3$
—	4	—	—	2225.13	14941	"		" " " " " 3F_2

are undoubtedly Cd III lines, some may be blends and one line, namely, 71096, is more likely to be a Cd IV than a Cd III line. Out of several plates taken during the investigation only two have been measured; intensities obtained from both the plates with and without inductance are given in the table. From these figures it is easy, in the light of the variation of intensities of the lines used by Gibbs and White, to infer the stage of ionisation of the respective lines. The doubtful cases have been marked 'IV' with a sign of interrogation.

It seems necessary to mention four cases where lines appear by violating the selection rule; but as they can be explained away in the following manners they have not been included in the tables. There is a line '59873' for the combination $4d^{10} 5s \ ^3D_1 - 4d^{10} 5p \ ^3F_3$ exactly equal to the difference of the respective term-values. Its wave-length, 1670.206, is double the wave-length of the

oxygen line 835.10; but it should be mentioned that other members of this group of lines have not appeared in the 2nd order. A line appears in the place of the combination $4d^5 5p\ ^3P_0 - 4d^5 5d\ ^3P_2$. Its intensity is 'o+' and 'o' with and without inductance, so it can be a Cd II line. The combination $5p\ ^3P_1 - 5d\ ^3F_3$ seems to appear with intensity 'o+' and 'o+' with and without inductance; but on a very close examination of Plate III (only in this plate the line has appeared), its appearance without inductance is seen to be extremely doubtful. It may be then a Cd IV line. The line '73592' for the combination $5p\ ^3F_4 - 5d\ ^1P_1$ has been found and measured in both the Plates II and III with intensities 'o' and 'o+', and 'r' and 'o+' with and without inductance. The author has also found a line '73597' in the zinc spectra which did neither fit into the analytical scheme for Zn II nor into that for Zn III and it could not be a Zn IV line on account of its behaviour with respect to inductance. Both these lines may be the same line and an impurity line.

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PROCEEDINGS
OF THE
INDIAN ASSOCIATION FOR THE CULTIVATION OF SCIENCE

A scientific meeting of the Indian Association for the Cultivation of Science was held on 6th April, 1943 in the Association Hall. Sir U. N. Brahmachari, Kt., M.A., M.D., Ph.D., presided. The papers read are given in the following pages.

J. N. MUKHERJEE,
Honorary Secretary.